

# **RUBBER-BASED COMPOSITE MATERIAL AND RUBBER ARTICLE USING THE SAME**

## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

5           The present invention relates to rubber-based composite materials and to rubber articles using the same. More particularly, the invention relates to rubber-based composite materials that can enhance durability of rubber articles and can reduce their weight when used as a reinforcing material for the rubber articles such as tires and belts, and to rubber articles, particularly tires, using the same.

### **Description of the Related Art**

10           As a reinforcing material for rubber-based composite materials to be applied for tires, belts and the like, organic fiber cords and steel cords are heretofore widely used. In such applications, strong adhesion between the rubber and the reinforcing material is important from the viewpoint of durability of the product. Therefore, in  
15           conventional composite materials of organic fiber cords and a rubber, the enhancement of the adhesion between both materials has been achieved by subjecting the organic fiber cords to dip treatment in a resorcin/formaldehyde condensate/latex (RFL) adhesive. Furthermore, in a composite of steel cords and a rubber, the steel cords are generally subjected to various plating treatment in order to enhance the adhesion between both  
20           materials.

          As a reinforcing material for rubber-based composite materials to be applied for tires, belts and the like, use of non-woven fabrics as well as the use of organic fiber

cords and steel cords is also known. For example, Japanese Patent Laid-open Publication No. Hei. 10-53010 proposes to apply a rubber-filament fiber composite using a non-woven fabric between a carcass layer and a sidewall portion of a radial tire in order to enhance the rigidity of the sidewall portion and to improve the driving stability of the tire without either damaging the original performances of the tire such as riding comfort and durability or complicating the production method.

As a reinforcing material for rubber-based composite materials, much attention is focused on non-woven fabrics because of their superior abilities to improve performance. The application of non-woven fabrics to tires for further improving their performance and to rubber articles, other than tires, which are required to have both rigidity and durability, have become to be examined. Moreover, the use of reinforcing materials containing non-woven fabrics is expected to be able to increase the design flexibility and the durability of the conventional rubber-based composite materials containing no reinforcing materials.

However, non-woven fabrics can not be enhanced their adhesiveness through the application of either the conventional dip treatment wherein organic fiber cords are dipped in an RFL adhesive or the plating treatment conventionally applied for steel cords. The reason why is that when these kinds of treatment are applied for non-woven fabrics, desired effects can not be obtained because a non-woven fabric becomes clogged to form a film and is reduced its contact area with the rubber to which the non-woven fabric is adhered.

Accordingly, an object of the present invention is to solve the above mentioned problems, to enhance adhesiveness between a non-woven fabric and a rubber, and to provide a rubber-based composite material the use of which as a reinforcing material for rubber articles such as tires and belts can improve the durability of the articles and can

reduce their weight. Another object of the present invention is to provide a rubber article using such a rubber-based composite material.

### SUMMARY OF THE INVENTION

5 The inventors of the present invention studied diligently to achieve the above mentioned objects. As the result, they have accomplished the present invention through their finding that the above mentioned objects can be achieved by applying a specific coating treatment by the vapor deposition method to the surface of the filaments constituting a non-woven fabric.

10 Accordingly, according to the present invention a rubber-based composite material is provided which comprises: a non-woven fabric; a coating of a metal or metallic compound reactable with sulfur, the coating being formed on a surface of the filaments constituting the non-woven fabric by a physical vapor deposition (PVD) method or a chemical vapor deposition (CVD) method; and a rubber that adheres to the  
15 coating and that covers the non-woven fabric.

Furthermore, according to the present invention a rubber product is provided, particularly tires, using the above mentioned rubber-based composite material as a reinforcing material.

20 The rubber-based composite material of the present invention can enhance the rigidity of the rubber article using the same as a reinforcing material without deteriorating the durability of the article. Particularly, in the case of a pneumatic radial tire, the application of such a rubber-based composite material to a sidewall portion of a tire can enhance the rigidity of the sidewall portion and can improve the driving stability of the tire.

## BRIEF DESCRIPTION OF THE DRAWINGS

The figure is a cross sectional view of a pneumatic tire of the present invention.

## 5 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereafter, embodiments of the present invention will be described in detail.

10 The non-woven fabrics applicable to the present invention are not webs formed by either twisting or weaving multiple bundles of filaments, but are those prepared by the carding process, the paper-making process, the air-laid process, the meltblowing process, the spunbonding process or the like. Preferably applicable methods for binding filaments in webs other than those formed by the meltblowing or spunbonding process include the welding process, the process using a binder, the water-stream-entangling or needle punch process in which filaments are entangled by the force of water streams or needles. Particularly, non-woven fabrics manufactured by the water-stream-entangling process or the needle punch process in which filaments are entangled by water streams or needles, or the meltblowing or spunbonding process are preferably employed.

15 The material for the non-woven fabric may be a single kind of fiber or a combination of plural kinds of fibers selected from natural macromolecule fibers such as cotton, rayon and cellulose; synthetic macromolecule fibers such as aliphatic polyamide, polyester, polyvinyl alcohol, polyimide and aromatic polyamide; carbon fibers; glass fibers; and steel wires. Filament fibers having a multilayer structure wherein a layer is formed of a material different than that of its adjoining layer may also be employed. Furthermore, composite fibers having a core-sheath structure in which 20 different materials are used in the inner layer and in the outer layer, a radiate shape, a

petal shape, a layered shape or the like, can also be employed.

In the present invention, the important fundamental factors for such non-woven fabrics include to have a structure in which a rubber can enter between fiber filaments and to have a structure in which the filament fibers and a rubber mutually form a continuous layer over a relatively long distance and a relatively wide area. Therefore, the diameter or the maximum cross-sectional dimension of the filament fibers is preferably in the range of 0.1-100  $\mu\text{m}$ , more preferably in the range of 0.1-50  $\mu\text{m}$ . The cross section of the filament fibers may have a circular shape or a shape other than a circle. The filament fibers may have a hollow portion.

The length of the filament fibers is preferably 8 mm or more, more preferably 10 mm or more. When the length is less than 8 mm, entanglement of filament fibers is not sufficient and the strength required as a reinforcing layer can not be maintained.

The mass per area (the mass per 1  $\text{m}^2$ ) of the non-woven fabric is preferably in the range of 10 to 300 g, more preferably in the range of 10 to 100 g. When the mass per area is less than 10 g, uneven non-woven fabric may be obtained because maintaining uniformity of the non-woven fabric itself becomes difficult and a composite prepared from the non-woven fabric and a rubber may show great random variations in strength, rigidity, and elongation at break after the composite is vulcanized. On the other hand, when the mass per area exceeds 300 g, a rubber tends not to enter the space inside the non-woven fabric though it depends on the fluidity of the rubber. Such a mass per area is not preferable in view of the peeling resistance of the rubber-non-woven fabric composite when the composite is used as a tire component.

In the present invention, a coating of a metal or metallic compound reactable with sulfur is formed on the surface of the filament fibers constituting the non-woven fabric by the physical vapor deposition (PVD) process or the chemical vapor deposition

(CVD) process. The forming of a coating by PVD or CVD has the advantage of causing less environmental pollution because of the use of no solvents. Furthermore, unlike the conventional dip treatment or plating treatment, such a process has another advantage of causing no clogging of a non-woven fabric since a coating is formed in the vapor phase.

Examples of the PVD process applicable to the present invention include the vacuum deposition such as resistance heating deposition and electron beam heating deposition; the molecular beam epitaxy process; the laser ablation process; the sputtering process such as DC sputtering, radio frequency sputtering, magnetron sputtering, ECR sputtering and ion beam; the ion plating process such as radio frequency ion plating; the ionized cluster beam coating process; and the ion beam process. Examples of the CVD process include the heat CVD process such as atmospheric pressure CVD, reduced pressure CVD and organometallic CVD; the photo CVD process; and the plasma enhanced (or assisted) CVD process such as DC plasma enhanced CVD, radio frequency plasma enhanced CVD, microwave plasma enhanced CVD and ECR plasma enhanced CVD. Among them, the sputtering processes, particularly the magnetron sputtering process, are preferably employed.

There are three main reasons for the fact that the sputtering methods are preferred. The first is that a coating can be formed on the surface of a non-woven fabric, a substrate, the temperature of which is low. The second is that the working pressure applied during the coating formation is as relatively high as  $5 \times 10^{-2}$  Pa to  $5 \times 10^1$  Pa and, therefore, the gas generating from the non-woven fabric does not influence very much. The third reason is that the particle sputtered from a target is highly possible to be scattered by the atmospheric gas such as argon (Ar) before its arrival at the surface of the non-woven fabric, the substrate, resulting from its straight travel, and

the so-called “diffraction” of the particle easily occurs. That is, the “diffraction” enables a coating to be formed well on a part of the non-woven fabric non-facing the target or shaded in spite of the extremely complex shape of the non-woven fabric.

The sputtering conditions, particularly the magnetron sputtering conditions are, for example, as follows. The atmospheric gas is an inert gas such as Ar, He, Ne and Kr, particularly Ar. As needed, a reactive gas, for example, O<sub>2</sub>, H<sub>2</sub>O and the like as an oxygen series, N<sub>2</sub>, NH<sub>3</sub> and the like as an nitrogen series, or CH<sub>4</sub> as an carbon series may be mixed to the inert gas. The mixing ratio by volume of an inert gas to a reactive gas is 100/0 to 0/100 (inert gas/reactive gas), preferably 100/0 to 20/80.

Furthermore, a bias voltage may be applied to a non-woven fabric, a substrate, as needed. In this case, the bias may be either DC or AC. In the case of AC biasing, the biasing mode is preferably the pulse or the radio frequency (rf). In the case of DC, the bias voltage is in the range of -1 kV to +1 kV.

The gas pressure may have any value at which the sputtering can be performed, but is preferably from  $1 \times 10^{-2}$  Pa to  $5 \times 10^2$  Pa, more preferably from  $5 \times 10^{-2}$  Pa to  $1 \times 10^1$  Pa. A power supply frequency (supplied to a target) may be either known DC or Ac. Generally, a DC power supply, radio frequency (rf) power supply and the like can be employed. A pulse power supply may also be used. The so-called “ionized magnetron sputtering” that causes inductive plasma between a target and a substrate to activate the particles under sputtering may be applied.

The average thickness of a coating formed by such a vapor deposition process is, usually from  $1 \times 10^{-10}$  m to  $1 \times 10^{-5}$  m, preferably from  $1 \times 10^{-9}$  m to  $1 \times 10^{-6}$  m, more preferably from  $5 \times 10^{-9}$  m to  $5 \times 10^{-7}$  m. If the coating is too thin, the adhesiveness will be insufficient. On the other hand, if too thick, the coating tends to separate from the substrate due to an internal stress of the coating. Such a coating is only required to

be formed on the surface of the filaments of the non-woven fabric in at least an amount the sulfurization requires. There is no need for a coating to be formed uniformly.

When the coating is exposed to the atmosphere during or after its formation, it sometimes reacts with oxygen or water vapor in the air, resulting in the contamination of impurities such as oxygen and hydrogen into the coating. If necessary, treatment such as plasma treatment, ion implantation, ion irradiation and heat treatment may be conducted after the formation of a coating to improve surface conditions, reactivity, internal stress and the like of the coating. Furthermore, it is desirable to fully clean the surface of a non-woven fabric, if necessary, before the formation of a coating.

Preferred cleaning methods include washing with a solvent, discharge, and a combination of the washing with a solvent and the discharge. The washing effect can be enhanced by a combination of two or more cleaning methods.

The metal or metallic compound reactable with sulfur that can be used in the present invention include alloys, oxides and nitrides. Any material that can be sulfurized during the curing of a rubber through its reaction with sulfur contained in the rubber can be employed. For example, Co, Cu, Zn, Cr, Al, Ag, Ni, Pb, Ti, W, alloys comprising two or more of the above listed metals and their compounds such as oxides, nitrides, carbides, sulfides and sulfates can be employed. Particularly, metals and alloys such as Co, Co/Cr alloy, Cu/Zn alloy and Cu/Al alloy, and their oxides can be preferably used. More preferably, Co and its oxides are used (see, Japanese Patent Laid-Open Publication Nos. Sho. 62-87311, Sho. 62-246287 and Hei. 1-290342). The compounds such as oxides, nitrides and carbides may be both those with a stoichiometric composition and those with a non-stoichiometric composition. Preferred are those having ratios of metal elements greater than stoichiometric values.

It seems that when an uncured rubber is applied onto a coating formed on the



surface of a non-woven fabric and adhered thereto on heating, adhesion occurs during the cure of the rubber through the sulfurization of the coating and the rubber. The cure and the sulfurization conflict with each other. In order for both reactions to be appropriately conducted, the reactivities about the reactions must be matched. In the formation of a coating by sputtering, a thin coating of a compound with a moderate sulfurization reactivity can be easily formed by the addition of an appropriate amount of a reaction gas such as oxygen and nitrogen to an inert gas such as Ar during the formation of the coating.

The combination of a non-woven fabric and a rubber to be used in the present invention is conducted by pressing a sheet-like uncured rubber composition from its top and bottom sides or from its one side with a press or a roll, thereby replacing the air present in the non-woven fabric with the rubber.

There are no particular limitations about the rubber composition that can be used in the present invention. For example, the rubber compositions conventionally used for tires and belts can be preferably employed. Therefore, rubber components may be both natural rubbers and synthetic rubbers. Additives such as curing agents, curing accelerators, reinforcing materials, antioxidants and softening agents may be optionally incorporated.

In the figure a cross sectional view of a pneumatic radial tire is shown, which is an embodiment wherein the rubber-based composite material of the present invention is applied. In this tire 1, both ends of a carcass layer 2 in which the cords contained in the layer are arranged in the radial direction of the tire are bent around a pair of right and left bead wires 3a and 3b. Two layers of steel belts 4 are disposed in a ring outside the carcass layer 2 in the radial direction. Furthermore, a tread rubber 6 is arranged in the road contacting surface portion 5 present outside the belt. Further, a

sidewall rubbers 7a and 7b are stuck on the carcass layer present on both sides of the tread rubber 3 through the rubber-based composite materials 8a and 8b. In this example, the rubber-based composite materials 8a and 8b are, respectively, arranged from the top ends of the bead fillers 9a and 9b to the vicinities of both widest ends of the belt portion with the rubber-based composite materials situated between the carcass layer 2 and the sidewall portions 7a and 7b.

In the present invention, such a rubber-based composite material is provided over a length of at least 10 mm within the regions extending from a bottom end of a bead portion to a widest end of a belt portion situated between a carcass layer and a sidewall or between the carcass layer and an inner liner layer. A rubber-based composite material with a length less than 10 mm adversely results in an insufficient effect of improving the driving stability.

As described above, according to the present invention, the adhesion between a non-woven fabric and a rubber can be enhanced. Furthermore, the use of the rubber-based composite material of the present invention as a reinforcing material for a rubber article can improve the durability of the article and can reduce the weight of the article. Particularly, its use as a reinforcement for reinforcing the side portions of a radial tire can greatly improve its durability under the running conditions, and the driving stability.

## Examples

The following examples are given for the purpose of illustration of this invention and are not intended as limitation thereof.

The surfaces (both surfaces) of a non-woven fabric (material of the fibers :

polyester, fiber diameter : 25  $\mu\text{m}$ , mass : 40  $\text{g/m}^2$ , thickness : 5 mm) were cleaned by a low-pressure plasma method under the conditions given in Table 1 and then a coating of Co and its oxide was formed on the surfaces by sputtering a Co target (purity : 3 N) under the conditions given in Table 1. The power density in the cleaning is defined as the magnitude of the power applied to 1  $\text{m}^2$  of the non-woven fabric. As a comparative example was prepared a non-woven fabric that had been applied with neither cleaning nor coating with Co.

Table 1

	Cleaning				Coating formation		
	Gas	Pressure (Pa)	Power density ( $\text{W/m}^2$ )	Time (sec)	Ar/O <sub>2</sub> Flow rate ratio	Pressure (Pa)	Average thickness (nm)
Example 1	Ar	100	600	10	50/0	0.7	$2 \times 10^1$
Example 2	Ar	100	600	300	50/0	0.7	$2 \times 10^1$
Example 3	Ar	100	600	300	50/4	0.7	$2 \times 10^1$
Example 4	Ar	100	600	300	50/13	0.7	$2 \times 10^1$
Example 5	O <sub>2</sub>	100	600	300	50/0	0.7	$2 \times 10^1$
Example 6	N <sub>2</sub>	100	600	300	50/0	0.7	$2 \times 10^1$
Comparative example	-	-	-	-	-	-	-

As a reinforcing layer, a rubber-based composite material obtained by integrally covering the non-woven fabric with an uncured rubber from both sides of the fabric, was stuck over a length of 50 mm from the top end of a bead filler between a carcass layer and a sidewall as shown in the figure. The thus obtained raw tire in which an uncured rubber composite material was applied as a fibrous reinforcing layer was shaped and then cured, resulting in a radial tire with a size of 195/60R15 containing a carcass ply of PET 1670 dtex/2. On the other hand, as a conventional example, a

radial tire was prepared in the same manner except applying no reinforcing material layer.

As for these tires, the driving stability test and the drum durability test under a high load were conducted.

5 <Driving stability>

A car (a domestically produced FF car with a 2000-cc engine) equipped with experimental tires was practically driven under the straight running and lane-changing conditions. The driving stability was evaluated from the driver's feeling. The evaluation was classified in comparison to the control as follows:

- 10 0 : It is equivalent to the control.  
+2 : It possibly is slightly better than the control.  
+4 : It is slightly better than the control.  
+8 : It is better than the control.

The total points are expressed in indexes based on the control of 100.

15 <Drum durability under a high load>

An experimental tire whose internal pressure had been adjusted to the maximum air pressure provided in the JATMA standard was left in a room at  $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$  for 24 hours. Then, its internal pressure was readjusted to the maximum air pressure. The tire was rotated on a drum 1.7 m in diameter at a rate of 60 km/h under the application of a load twice the maximum load provided in the JATMA standard. The distance traveled before the occurrence of a failure was measured and indicated as an index based on that of the conventional tire equal to 100. The greater the index, the better the result. The results are given in Table 2.

Table 2

		Conventional example	Comparative example	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Results	Driving stability	100	110	118	119	115	113	116	117
	Practical durability	100	174	180	193	191	182	190	189